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Modelling of the Municipality Entrepreneurial Community Functioning Using the Methods of System Dynamics

D.B. Berg*. A.O. Kolomytseva**
A.V. Apanasenko*. K.F. Isaichik*

**Ural Federal University, Yekaterinburg,*
Russian Federation (e-mail: bergd@mail.ru stacy-chan@yandex.ru k-isaichik@mail.ru)
***Donetsk National Technical University,*
Donetsk, DPR (e-mail: anniris21@rambler.ru)

Abstract: The purpose of this research is to develop an imitation system-dynamic model for the municipality entrepreneurial network functioning. The model is implemented on an experimental level in the environment of simulation moderation Powersim Studio 7.

On the one hand it gives us the opportunity to monitor the state of communications and exchange at various periods of time. On the other hand it allows to determine the architecture of links, levels and flows of exchange between network participants as well as the most effective conditions for the realization of commodity-money relations both inside and outside the network. The introduction of inside money into the entrepreneurial network is considered to be a method of exchange effectiveness increase. The parameter, reflecting their usage in the network, acts as the main regulator of exchange and at the same time it is the controlling parameter of the model. Simulation experiments result, expressed in resulting coefficients (liquidity, cooperation, exchange synchronization), allows you to assess numerically the system state at different control parameter values. It makes the designed model an effective support tool for optimizing decisions and managing a complex economic system, which is the entrepreneurial network of the municipality.

Keywords: entrepreneurial network, municipality, simulation modelling, system dynamics, decision support, administrating, commodity and money relations, inside money.

1. INTRODUCTION

Nowadays world economy has an evident tendency of changing the object of economic management. In an industrial society, enterprises and their market-based associations acted as such an object. Whereas in a post-industrial society, the networks of enterprises and organizations (entrepreneurial networks) become an object of management under the influence of globalization processes. The entrepreneurial network is a set of business entities. They unite their efforts and realize their interests on the basis of optimality criteria functioning, and they are also connected with satisfaction of social, economic, production, technical and other internal and external interests of the network structure itself.

The focus shifting from an individual firm functioning to entrepreneurial network activity as a participant in a competitive struggle, causes changes in the traditional ways of business management. There is a need to monitor and control simultaneously both external interrelationships of the network and the relations of its individual participants with each other. This inevitably complicates the management process and causes the relevance of scientific research in this area.

Network forms of business organization are an object of foreign and Russian scientists research. I. Ansoff, R. Ahrol, A. Buzgalin, S. Dyatlov, V. Inozemtsev, M. Castells, M. King, P. Kotler, V. Lazarev, Y. Osipov, S. Parinov, V. Polterovich, M. Porter, C. Hakansson studied issues of methodology of network economy formation and development. Thus, the works of A. Asaul, M. Geraskin, V. Dementiev, R. Rudensky, T. Klebanova, O. Eliseeva, O. Zvereva, A. Kolomytseva, V. Kravchenko and V. Khristianovskiy consider models and methods of constructing industrial-commercial and information links in complex economic systems, cluster forms of economic activity organization, nonlinear models of innovation activity, methodology of business networks formation and management. This theme is also touched upon by S. Avdasheva, M. Beck, N. Beck, S. Guriyeva, T. Dolgopyatova, V. Katkalo, R. Kachalov, G. Kleiner, S. Kuschem, B. Milner, J. Popova, N. Popov, V. Radaev, V. Rebyazina, A. Sterligova, M. Smirnova, V. Tretyak, O. Tretyak, J. Pappe, M. Sheresheva, O. Yuldasheva and A. Yakovlev, who study the formation and functioning of various inter-firm relations between economic agents. Methods of cellular automata, agent-oriented and system-dynamic models are used to calculate the trajectories of business communities development.

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The main difficulty in entrepreneurial network managing is making management decisions in situations of uncertainty. The activity of every enterprise inside the network and entrepreneurial network as a whole is influenced by a variety of factors, which must be taken into consideration. The authors of the study see the class of system-dynamic simulation models as the most suitable of this category of methods, as on the one hand they fully reflect the network structure, and on the other hand they monitor the state of the system at different time intervals.

This study substantiates the possibility of using system-dynamic simulation modelling for investigating the effectiveness of exchange and communications in the entrepreneurial network, which is formed by transactions (links) between participants of the municipality business community. Thus, the purpose of the research is the development and implementation of an imitation system-dynamic model of the local municipal economy on an experimental level. Its results will allow to take more rationally administrative decisions as to effective communications organization and harmonize the terms of exchange between participants in this entrepreneurial network.

2. METHODOLOGY OF SYSTEM-DYNAMIC MODELLING

2.1 Research objective description

The municipality entrepreneurial network is a municipal economy internal market. The network is represented by 12 network partners: 11 enterprises, population (households) and environment.

The population can be considered a full-fledged network partner, since it does not only consume the products of most enterprises of the municipality, but also supplies them with the most important production resource, that is labour force. The commodity and money flows between the network participants are reflected in its sociograph (fig. 1).

Since this business network is characterized by a large number of stereotyped elements and links, all enterprises of the municipal economy were divided into 4 branches in order to build the model:

1 – Crop production and animal husbandry;
2 – Food industry;
3 – Services;
4 – Population (households);

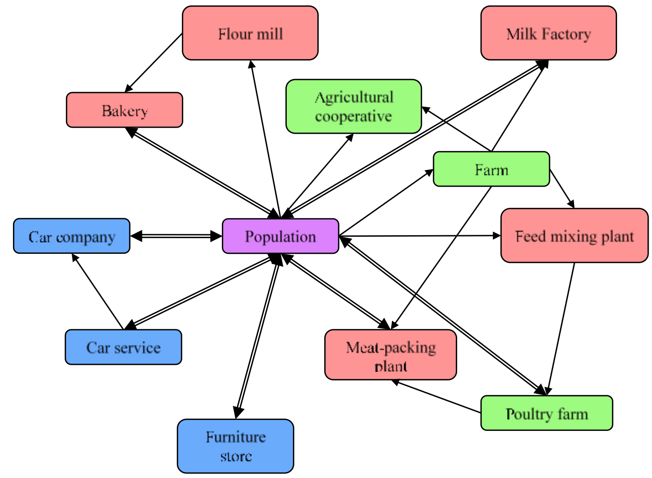

Fig. 1. Municipality entrepreneurial network sociograph

This allowed to enlarge the network sociograph, which took the following form (fig. 2):

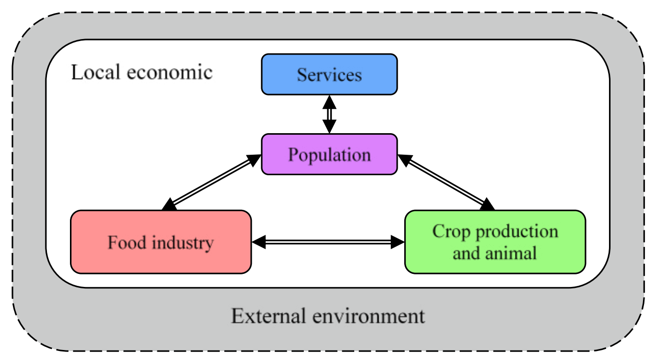

Fig. 2. Municipality entrepreneurial network sociograph enlarged by industries

As we can see in fig. 2, the central node of the municipality network is the network partner "Population", which has commodity-money relations with all other participants of the network. "Crop production and Animal Husbandry" and "Food Industry" are connected with each other and with the "Population", and "Services" are only connected with the "Population". All connections are reciprocal i.e. every network member buys the products of the other. The external environment has also been put on the scheme of the sociograph, since the system is not closed and commodity exchange does not only happen between the network participants but also with environment agents.

Commodity exchange within the network is reflected in mutual consumption matrix (mutual payments), built on the basis of average statistic data and municipality residents consumer basket analysis. In the frames of this study, this matrix was also enlarged taking into account the selected industries. Besides, numerical indicators of commodity exchange for the external environment were obtained on the basis of matrix balance data. All indicators are given in monetary terms. The transformed matrix has the following form (Table 1):

Table 1. Mutual consumption matrix (mutual payments)

	Reciprocal goods and money exchange, thnd.rub./mo.				
	1	2	3	4	Envr.
1	0	6023,58	2966,67	0	205069,83
2	8303,83	0	15854,25	0	29798,92
3	685,58	18135,33	0	1423,50	15478,92
4	0	0	1423,50	0	879,75
Envr.	205069,83	29798,92	15478,92	879,75	0

In addition, within the framework of this study, it is supposed to use the so called internal money-virtual units of calculation, that act as a means of exchange between network participants in case of lack of real money.

2.2 Assumptions of the model

On the basis of the above-stated information for the model of the municipality entrepreneurial network the following assumptions were made:

- all network participants have bilateral commodity-money relations (they consume each other's production);
- commodity exchange does not only happen between network participants, but also with external environment representatives;
- each enterprise produces (according to the plan) as many products as its partners consume, including the external environment;
- at the moment the network starts functioning, all network partners have zero commodity and money stocks;
- the possibility to include or exclude the inside money usage is taken into account.

2.3 System-dynamic model realization

The system-dynamic model of the municipality activity was realized in the simulation modelling environment of Powesim Studio 7. The interface of the model is shown in fig. 3.

As we can see on fig. 3, all model elements were grouped into six logical entities. Four of them consistent with network partners, one – with environment, and another one (exchange management regulator) combines resulting indexes calculation with control model parameters. All blocks, except the last one, have a typical structure. Each of them contains two levels, i.e. the level of commodity stocks and cash resources with corresponding incoming and outgoing flows, forming the level values.

The block also has a variable, containing the consumption vector of a particular network member, and a variable that reflects the amount of inside money used by the network partner in the process of exchange. Resulting indexes entity includes inside money usage calculation, goods with money supply coefficient calculation, cooperation coefficient. The block of resulting indicators includes the inside money usage calculation, the goods supply coefficient calculation with money and the cooperation coefficient.

The input data of the model are variables, containing network partners reciprocal exchange vector. Their values are formed on the basis of mutual consumption matrix (tab.1). An element of randomness is introduced into the calculation of these indicators to model the activities of a real business network, where actual output and consumption of products may differ from the planned one.

The output data of the model are its levels values, containing information about network partners financial resources and reflecting the ability of enterprises to further participation in exchange. And there are also three coefficients, reflecting the system state:

Goods with money supply coefficient (liquidity) (KS) characterizes the amount of money, circulating in the system relatively to the amount of goods. It is calculated as a quotient of the network money flow division by the total commodity-cash flow. The calculation formula is shown in tab. 2.

The cooperation coefficient (KC) characterizes the link effectiveness and exchange level between different entrepreneurial network agents/participants. It is calculated as a ratio of inside financial flows (not belonging to the environment), among all network financial flows. The calculation formula is shown in tab. 2.

The commodity and cash flows time intervals synchronization coefficient characterizes the correlation degree between commodity and cash flows for the analyzed period of time. It is calculated by the formula:

$$R = \frac{\sum xy - \left(\frac{\sum x * \sum y}{n}\right)}{\frac{\left(\left(\sum x^2 - \left(\frac{\sum x^2}{n}\right)\right) * \left(\sum y^2 - \left(\frac{\sum y^2}{n}\right)\right)\right)^1}{2}}, \qquad (1)$$

where n – number of observation,
x – input variable,
y – output variable.

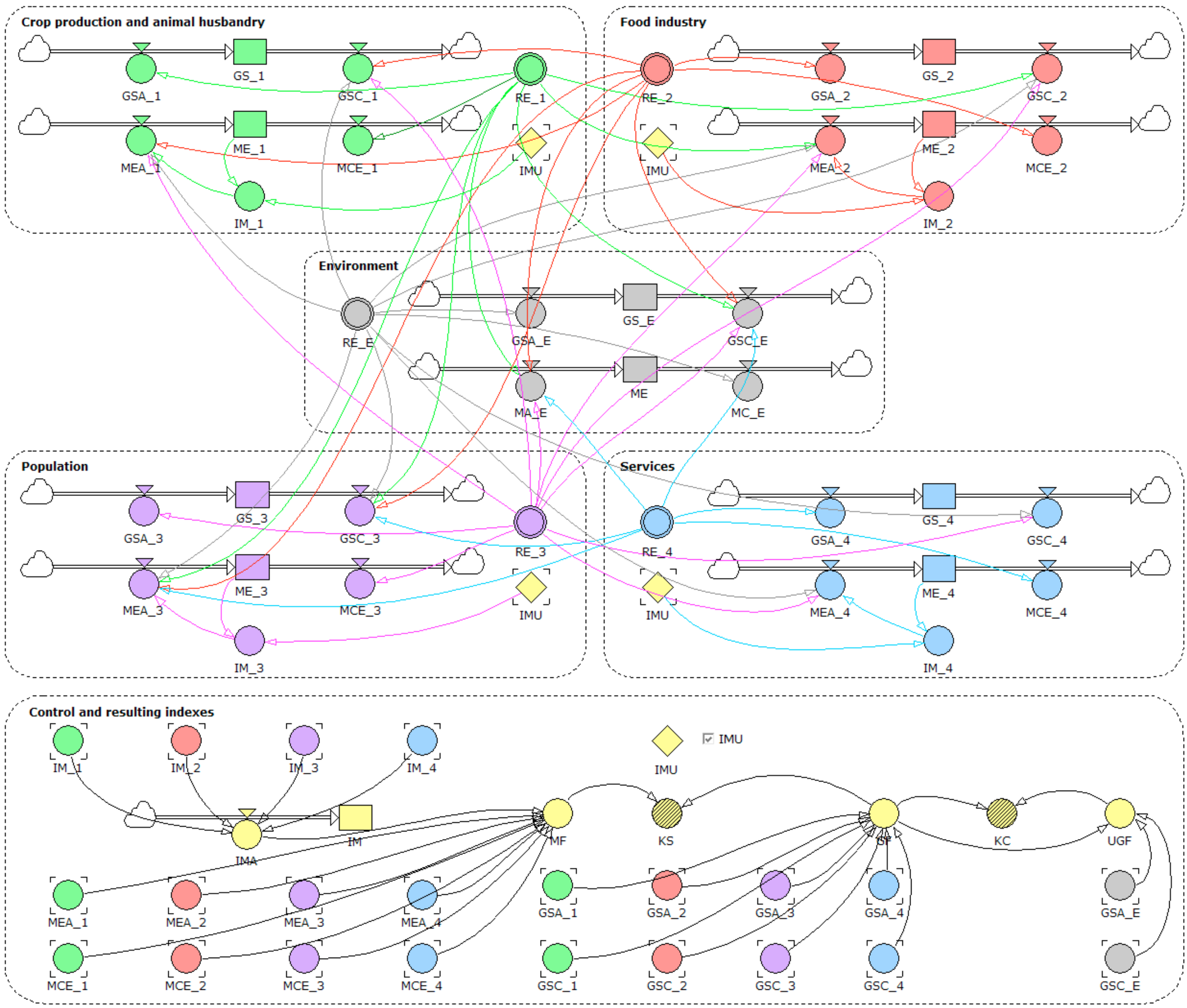

Fig. 3. Municipality entrepreneurial network functioning system-dynamic model interface

Table 2. Model equations in a generic form

Equation	Variables
1. Reciprocal exchange vector: $$\mathrm{RE\_K(t)} = \{w_1^k, w_2^k, w_3^k, w_4^k, w_5^k\}$$	wherew_n^k – reciprocal exchange vector element, relevant to n-th partner production cost that was consumed by k-th partner, if n=k, then $w_n^k = 0$
2. Network partner goods stock number: $$\mathrm{GS\_K(t+1)} = \mathrm{GS\_K(t)} + \mathrm{GSA\_K(t)} - \mathrm{GSC\_K(t)},$$ where $\mathrm{GSA\_K(t)} = \sum_{k=0}^{n} w_n^k$; $$\mathrm{GSC\_K(t)} = \sum_{k=0}^{n} w_k^n$$	where w_k^n – reciprocal exchange vector element, relevant to k-th partner production cost that was consumed by n-th; GSA_K – goods stock arrival to k-th network partner; GSC_K – goods stock consumption by k-th network partner

Equation	Variables
3. Amount of money, available to network partner for exchange: $ME\_K(t+1) = ME\_K(t) + MAE\_K(t) - MCE\_K(t),$ where $MAE\_K(t) = \sum_{k=0}^{n} w_k^n + IM\_K(t),$ where $IM\_K(t) = \begin{cases} \text{if } IMU = 1 \text{ и} ME\_K(t) < 0 \\ \text{then } ME\_K(t) \\ \text{else } 0 \end{cases};$ $MCE\_K(t) = \sum_{k=0}^{n} w_n^k$	where MAE_K– money arrival to k-th network partner; MCE_K– money consumption by k-th network partner; IM_K – inside money consumption by k-th network partner; IMU – constant reflecting inside money usage in the system (0 – not used, 1 – in use)
4. Total amount of used inside money: $IM(t+1) = IM(t) + IMA(t),$ where $IMA(t) = \sum_{k=0}^{n} IM\_K(t)$	where IMA – amount of inside money, injected in financial network system for money supply shortage compensation
5. Goods with money supply coefficient: $KS(t) = \frac{MF(t)}{MF(t) + GF(t)},$ where $MF(t) = \sum_{k=0}^{n} MAE\_K(t) + MCE\_K(t)$ $GS(t) = \sum_{k=0}^{n} GSA\_K(t) + GSC\_K(t)$	where MF – sum money flow within the entrepreneurial network; GF – sum goods flow within the entrepreneurial network
6. Cooperation coefficient: $KC(t) = \frac{GF(t)}{GF(t) + UGF(t)}$ where $UGF(t) = GF(t) + GSA\_5(t) + GSC\_5(t)$	where UGF – sum reciprocal goods flow for exchange with environment.

The controlling model parameter is a constant, regulating inside money usage in the entrepreneurial network. If its value equals to zero then inside money is not used, but if it equals to 1, then it is used. The model interface is provided with a switch to control the value of the constant.

The interrelation of various municipality entrepreneurial network functioning indexes, commodity and money flows between them reflect in variable and model level equations. These equations are given in a generic form in tab. 2. The following notation keys are used in the equations:

n – network partners sequence number set (n=1..5);

k – current network partner number (k ϵ n), where k=5 – environment;

t – modelling step.

Two years were chosen for the modelling period and the modelling step is a month. Such parameter values make it possible to monitor the system functioning in dynamics based on a small amount of input data.

3. EXPERIMENT RESULTS UNDER THE CONDITION OF PUTTING INSIDE MONEY INTO CIRCULATION

Two experiments have been conducted for the demonstration of municipality system-dynamic model work. In the first case the control parameter IMU took the value of 0, i.e. it was supposed that the inside money within the entrepreneurial network financial system was not used. In the second case the control parameter IMU took the value of 1, i.e. the usage of inside money was added if there was a shortage of money supply for commodity and money exchange realization.

Graph of resulting indexes after the first experiment are shown in fig. 4 and fig. 5:

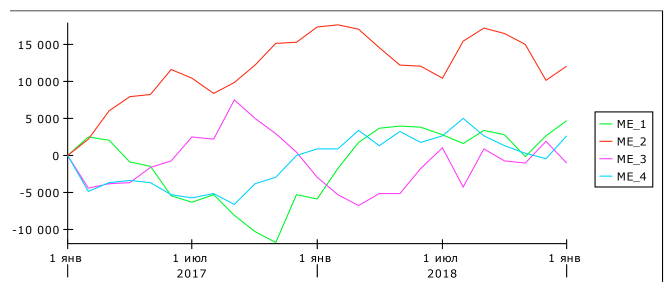

Fig. 4. Graph of ME_K levels (experiment #1)

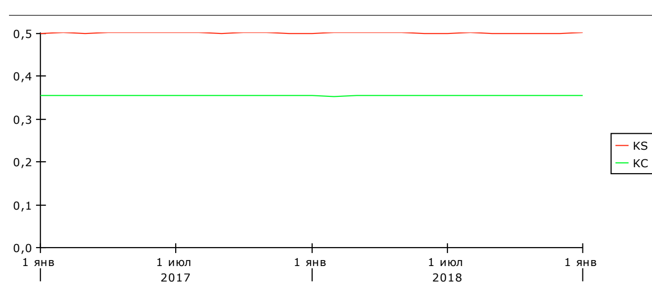

Fig. 5. Graphics of resulting coefficients (experiment #1)

As we can see in the graphs, ME_K levels values often drops below zero. This is attributable to the fact that the money, paid for the goods at the current step of modelling, only become available for exchange at the next step, and to the fact that there is a difference between planned and factual production and consumption values. Such a situation affects the entrepreneurial network activity in a negative way because negative money balance makes enterprise involvement in exchange impossible or extremely difficult. There is a need in crediting or existence of money stock bur it is not always possible for municipality enterprises. Resulting coefficients values KS and KC are within the normal range but it only matters if all members are able to compensate the medium of shortage, which seems to be unlikely.

This problem can be solved by inside money insertion. It is demonstrated during the second experiment:

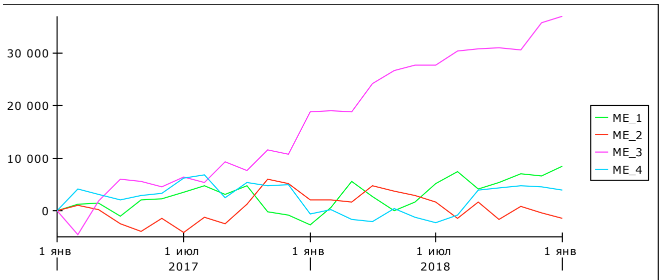

Fig. 6. Graph of ME_K levels (experiment #2)

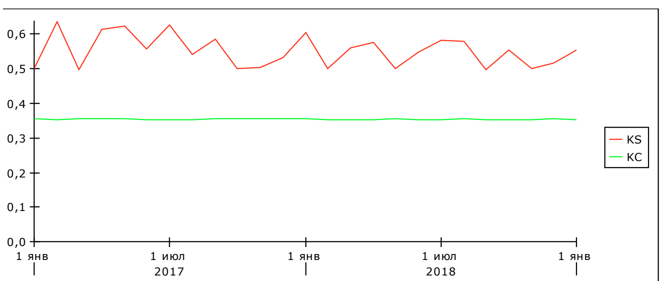

Fig. 7. Graph of resulting coefficients (experiment #2)

The graphs (pic g. 6 and fig. 7) show that after inside money was added ME_K levels values, and even in the most unfavorable scenario they are hovering around zero, i.e. all network partners almost always have a possibility for exchange, which positively affects the entrepreneurial network activities. The assumption about the inside money insertion necessity is confirmed by the values of the resulting indicators. The value of one of them (KC) has not changed, and the value of the other (KS) has increased.

In addition, there was calculated another resulting index – R (goods and money flow synchronization coefficient) on the basis of the data received in MS Excel. In the first case its value was 0.85 and in the second one it was 0.91, i.e. it has also increased. Thus in general, the received indexes characterize changes in the system as positive. The results obtained in the course of work are agree well with the real economic data and the results of calculations based on the agent-oriented model.

4. CONCLUSION

The developed municipality system-dynamic activity model and its results can be used as an effective decision-making support tool for exchange and communication managing between municipality economy network participants The results of numerous experiments confirm the assumption that inside money insertion improves exchange processes within the network, making them more stable, what will affect its activity results in a positive way. The possibility to rely on the predicted index values obtained in the course of simulation experiments, rather than theoretical conclusions, will greatly facilitate the adoption of managerial decisions, making them less risky. Furthermore, the system-dynamic simulation modelling allows to monitor network exchange process at different periods of time, detectits weak points or predict its state in future, particularly in terms effective communications organization and effective exchange conditions coordination between agents/participants of municipality entrepreneurial network.

The results of the regions development trajectories calculation based on the system-dynamic model proposed in this paper can be used in future to predict the magnitude of the barriers to regional development.

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